32. Rigler, O.: Die Aktinomykose in Thüringen, Inaug.-Dissert., Jena, 1991.
33. Roth, A. W.: Case of Actinomycosis of the Tongue, Jour. Oklahoma Med. Assn., 1916, 9, 9.
34. Ruhräh, J.: Actinomycosis in Man with Special Reference to the Cases which have been observed in America, Ann. Surg., 1899, 30, 417–451; 1900, 31, 235–241.
35. Samter, O.: Fälle von Actinomykosis, Berl. klin. Wchnschr., 1888, 25, 778.
36. Schartau, H. F.: Ein Beitrag zur Kenntniss der Aktinomykose, Kiel, Jensen, 1890, 43 pp.
37. Schlonge: Zur Prognose der Aktinomykose, Arch. f. klin. Chir., 1892, 44, 863–875.
38. Schwienhorst, M. H. R.: Ein Beitrag zur Casuistik der Zungenaktinomykose, Giessen, Klindt, 1903, 42 pp.
39. Smirnow, G. I.: Die Aktinomykose der Zunge beim Menschen, Med. Wschr., Berlin, pp. 133–136.
40. Ullmann, E.: Beiträge zur Lehre von der Actinomycose, Wien. med. Presse, 1888, 29, 1769, 1812, 1853.
41. Zuhrs: Quoted by Krymow.

PAIN IN THREATENED AND REAL GANGRENE OF THE EXTREMITIES: ITS RELIEF.

By Bertram M. Bernheim, M.D., F.A.C.S.,
Baltimore, Md.

In no pathological condition does pain play a more important role than in gangrene of the extremities. One of the earliest diagnostic signs of a failing circulation, it influences the whole course of the disease by reason of the fact that upon its control, more than any other single factor, depends the success or failure of whatever form of treatment may be outlined. It follows, too, in consequence that in addition to its other qualities, pain in gangrene is of real prognostic importance.

The underlying condition in cases of threatened gangrene is a diminished blood supply. This may be manifested by an early numbness and tingling of the toes and feet and by blanching of the extremities, together with a cold feeling; or, the first complaint may be an inability to walk any great distance without resting at short intervals, so-called intermittent claudication. But whatever the early signs may be, in practically every instance a certain amount of pain is complained of in addition to the other symptoms noted. Indeed, so prominent is this feature that those who see most of the circulatory diseases of the extremity have come to feel that when a patient comes in complaining of pain in his limbs of such severity that it wakes him at up night, the condition is very likely to be associated with a diminution of the blood supply.

In some way this pain must be associated with the ischemia consequent upon blocking of the main vascular channels, but just why there should be pain at all I am at loss to say. It is

known that nerve tissue withstands ischemia less well than tissues of other types, so that one might think that the underlying cause of the pain is a nerve degeneration. As a matter of fact, circulatory deficiencies of the extremities are usually diagnosed at first as some form of neuritis, and it is only when the true state of affairs is discovered that the real malady becomes apparent. But while there may possibly be some low-grade inflammation around the nerves of the extremity affected, no one has thus far noted a real nerve degeneration such as might give rise to the pain so bitterly complained of by practically all patients who are threatened with gangrene of an extremity. The most that one can say is that in those extremities whose blood supply is diminished there is a pain that increases in direct ratio as the gangrene becomes more evident, and in just so far as one is able to combat successfully the encroachment of the gangrenous process will the pain be relieved. In other words, relief of pain in these conditions really amounts to improving the circulation to such extent that the gangrenous process is halted. This fact appears to discredit the nerve degeneration theory of the pain, since if a nerve is degenerated it is hardly likely that regeneration would come to pass immediately upon an improvement in circulation. Nerve regeneration ordinarily is a very slow process.

In almost every case of threatened gangrene the main vascular channels are occluded from one cause or another, at some point in their course, so that, for all practical purposes, measures of relief amount to developing an adequate collateral circulation. The only trouble is that the development of a collateral circulation sufficient to nourish the parts is a time-consuming procedure, and not only is it time-consuming, but it involves the use of certain forms of therapy which in themselves seem to give rise to more or less discomfort. Therefore, the pain element is of extreme importance because upon the patient's ability to withstand its ravages, frequently depends the success or failure of the whole treatment.

One might think that it would be a simple matter to give these patients sedatives of one kind or another and thus put them in position to stand almost any amount of pain; but experience has shown that this is all but impossible, because the pain is of such a character that unless huge doses of morphine are given little or no effect is seen, and everyone knows what large doses of morphine will do to a person when given over a long period of time. For the successful handling of cases of threatened gangrene occupies a period often of months and even years, so that if one is to have any success at all he had best beware of sedatives other than the milder ones, such as codeine and the bromides. Sodium bromide has been of great assistance, and when judiciously employed may be continued over an indefinite period of time.

Rest of course is of extreme importance, but here, again, one

is confronted with a situation that is unique to this condition—namely, a tendency upon the part of the patient to get up and walk about whenever his sufferings become acute. The whole picture, the whole conglomeration of features connected with extremity gangrene, differs vastly from any other surgical condition with which I am familiar. Ordinarily if one has pain he stays in bed; he takes a sedative or a hot-water bottle or something equally efficacious and awaits results. In this condition the patient seems unable to rest; it takes huge doses of sedatives to relieve him, and since it is impossible to continue this practice over long periods of time, he resorts to walking up and down his room until, thoroughly exhausted, he falls over into a troubled sleep.

Rest is important none the less. It is difficult to obtain at times, but much can be done by perseverance, especially if one can get his patient to the point where he will consent to remain in bed even if he has pain. To do this, one is at times forced to promise the patient that he will not be permitted to suffer too much, by which he will understand that morphine will be given if need be. This gives him something to hang to while it gives the surgeon an opportunity at least to start those measures of relief which have for their objective the development of a collateral circulation in the affected limb adequate to sustain tissue life. All of these measures have to do with contracting and dilating the larger and smaller bloodvessels—so called bloodvessel exercise—since it is felt that spastic contraction of terminal vessels accounts in no small degree for the diminished blood supply carried down the limb. It is either a spastic condition or a collapse of these vessels due to disuse, but in either case alternate contracting and dilating of them has been found beneficial in that it is easier for blood to circulate through them. The cause of this collapsed condition of the vessels at first sight seems to be due to the fact that with the main vessels occluded little if anything is going through them, so that it is only natural that they should be in a state of collapse. At the same time one must not lose sight of the fact that in general those who are suffering with threatened gangrene of an extremity, unless they have a generalized arteriosclerosis with a coincident nephritis, are usually found to have a distinctly lowered blood-pressure. So that in certain cases I am sure there is not sufficient force back of the blood stream to send it down the collateral channels as long as the smaller bloodvessels are in a state of either spasticity or collapse from disuse.

I usually start my patients off by having them give the affected part an alternate hot and cold plunge by means of two pails of water. One of these pails is filled with iced water while the other is filled with water almost at the boiling-point. The patient plunges his foot first into the cold water, leaves it there a second or two, and then without drying it at all, plunges it immediately

into the hot water. After it has been in that a few seconds he puts it back into the cold water and from there again into the hot water, continuing this alternate cold and hot plunge for about five minutes, finally ending up with the hot-water plunge. By this means his vessels alternately contract and dilate, and in many cases the process is quite obvious to the eye by the blanching and reddening of the skin of the affected part. The process is finished off with the vessels in dilatation. The patient is put through these exercises three times a day if he can stand it. Sometimes the patient is unable to stand this treatment at all, although, as a rule, he gets used to it and is able to go through the exercise without difficulty. In most of the cases that have been unable to stand it there has been some degree of ulceration either around the base of the nails or at some place on the foot. At the conclusion of the baths the foot is dried off thoroughly and the whole foot and leg are well oiled with any kind of oil, such as olive oil, cocoa butter, etc., particular attention being given the parts around each nail and between the toes. The patient is then instructed to lie down and keep the foot warm for at least an hour. It is not sufficient to carry out this exercise merely with the water in shallow pails; it is far better to have a deep bucket so that the whole leg can be put in the water almost up to the knee.

In between these baths I am in the habit of having the patient use an electric vibrator, such as is used by barbers for face and scalp massage. This is used over the entire leg and foot, the patient himself carrying it out. At first the skin is liable to be slightly irritated by the machine, but this very quickly wears off and the patient is able to use the vibrator for five or ten minutes four or five times a day, after each application the whole leg being anointed with oil. I lay great stress on this lubrication, not because of any inherent qualities in the oil itself, but because it is extremely important that the skin in these cases be kept in as healthy a condition as possible; and that all scratches, cracks and abrasions be studiously avoided, since only too frequently they are the starting-points of infections and ulcerations. By means of the baths and the use of the vibrator, together with rest and perhaps a small quantity of bromide, the acute condition is very frequently overcome so that it is possible to go a trifle more slowly. After two or three weeks of these frequent hot and cold baths I usually have the patients employ them only in the morning and in the evening, although they are encouraged to use the vibrator as often as they wish. This in my experience has been the great pain reliever, so that its use can be regarded as a sort of index as to the amount of pain the patient is suffering.

In addition to these measures of exercise I use one other, namely, that of occluding all the blood through the affected part by means of a bandage applied above the knee after the leg has been elevated

and all blood expressed out of it. This measure is carried out as follows: With the foot and leg slightly elevated a muslin bandage is applied, starting at the toes and running up with increasing pressure above the knee. At that point another bandage is placed around the leg in the form of a wide constricting bandage. This is left in place for about one minute, during which time the bandage that has been put on from the toes upward is released. At the conclusion of this time the constricting bandage is suddenly cut and the leg held down over the side of the bed. With the constricting bandage in place the leg will have a real cadaveric appearance, while as soon as it is cut there will be an immediate rush of blood toward the extremity, its progress being noted by the fiery red blush to the skin. If one carries out this procedure in both legs it will be found that blood flowing to the toes will occupy a period of from five to fifteen seconds in the healthy extremity, while it will take from thirty to sixty or even one hundred seconds or more in the affected extremity. This is sometimes called the reaction time of the bloodvessels, by which is meant the time it takes the blood to reach the terminal vessels. Naturally in states of threatened gangrene the blood is unable to get down to these terminal vessels rapidly; in other words, the reaction time is slowed. As the collateral circulation develops the reaction time is increased and tends to become normal. The method that has just been explained is that of Moskowicz, and in other conditions is used to determine the state of collateral circulation. I use it in these states of threatened gangrene because of my feeling that it helps to dilate the collapsed bloodvessels. I am accustomed to use it on all patients once a day, but here again there are limitations because of the pain it may occasion. If carefully carried out, however, there need not be any great amount of discomfort.

In addition to all these measures I have been accustomed to give all patients a course of Ringer's solution by means of the duodenal tube. Just why Ringer's solution should help in these conditions it is difficult to say, but for some years now it has been felt that by this means the viscosity of the blood could be lowered and that this was much to be desired. The fact remains that there has been a curious alleviation of pain in many of the cases coincident with the giving of Ringer's solution. Many of these individuals object to taking it by means of the duodenal tube, so they are permitted to drink it, but the solution has a definite salty taste and it is impossible to take it in great quantities or over a long period of time by mouth. Furthermore, it is possible that the character of the solution is changed by the gastric juices, so that it is much better to give it by means of the duodenal tube. Even by this means there comes a time when the patient is unable to continue the use of the solution; he feels nauseated and vomits.

This usually comes on after a two or three weeks' course, at which time it is best to discontinue its use for some weeks and later to resume it. The amounts given vary, but generally about one liter is given a day either at one sitting or at two. In certain cases as much as two or three liters have been given.

I have never had any great success with baking. On the contrary most of my patients have disliked it because they maintained it increased their pain—and this in spite of the fact that the measure has been instituted with care and they have not been subjected to specially high temperature. The various baking ovens have been used as well as electric-light ovens. Most of the patients describe their pain as of a "burning" character, and they insist that dry heat exaggerates it. Furthermore, they frequently seem most comfortable when the foot is almost or entirely uncovered and exposed to the air. In the acute exacerbations any covering that comes in contact with the affected part gives rise to excruciating agony.

Ulcerations, small or large, practically always give rise to exquisite pain and the toes affected—for the ulcers are practically always at or around the nails—assume a purplish-red, swollen appearence, at times looking as if they would burst open at any moment, and would take great joy in doing so. Conservatism—ultra-conservatism, is to be pursued in the presence of these affairs, for while ulcers they are, they are also gangrenous patches in reality, and it is best to let them alone, since they will heal only if the blood supply to the foot is improved. Wet boric compresses or salt solution may be used, occasionally boric ointment or plain vaseline, or anything bland and mild. The parts must be kept thoroughly clean at all hazards to avoid ascending infection, and as little sloughs appear they should be gently wiped away. If the ulceration progresses and involves the phalanges, adequate drainage should be provided, but a waiting course is always to be pursued.

Operative measures, even minor ones, only too often end in disaster, since with the terminal circulation already in a precarious state the resultant wound not only refuses to heal but often sloughs more than ever, with the result that more bone becomes involved, tendons become exposed and slough, and finally the process spreads up the foot. If then further operative measures are invoked the same story is repeated—it is usually one amputation after another until the whole leg is involved. Far better is it to be conservative. The patient may suffer a little longer, for in the vast majority of instances the ulcerated areas are exquisitely sensitive and each dressing is an agony; he may get extremely restless and the surgeon may at times be tempted almost beyond endurance to use the knife, but waiting is the only way I know

to achieve success. The cause of the trouble is not in the toes nor in the foot; it is in the occluded bloodvessels higher up, and one must bend his efforts to rectify this condition. As it tends to be corrected the pain becomes less excruciating, the edema of the foot and toes begins to subside, the color becomes more normal and healthy edges appear around the ulcers, which slough out and then heal, permitting the patient first to bear a little weight on the affected foot and then walk.

Should the measure as outlined fail, or should the pain become so unendurable as to preclude further conservative measures, one may resort to certain operative procedures. In a few instances it may be possible to do an arteriovenous anastomosis, by which means theoretically the blood current is shunted from the artery which is occluded below to the accompanying vein which is supposed to be patent throughout its extent. I have carried out a number of these operations and without mortality, but the procedure has gradually been discarded because experimentally at least it seems as if the blood current progresses down the vein but a short distance, after which it is turned back through venous lines of least resistance toward the heart. However this may be, certain of my patients appear to have benefited greatly by the operation, the gangrenous process was stopped and their pain relieved. It is only fair to say that the best results were achieved in young individuals who were suffering from Raynaud's disease. I do not believe an arteriovenous anastomosis is indicated in any of the more common forms of gangrene, since in most of those that have come under my observation the veins are involved in the process to a great extent, and in the very nature of things it would be impossible for the arterial blood to circulate through them. It may be that if one could get these cases in their earliest stages such an operation might be followed by good results, but I am of the opinion that equally good results could probably be obtained by other means if they were promptly instituted in the very earliest stage of gangrene. One must always remember that an artery which is occluded, say from the popliteal space down to the foot, is liable to undergo gradual occlusion all the way up to and into the pelvis, so that even if a successful arteriovenous anastomosis could be performed it would probably become occluded in the course of time by the ordinary progress of the disease.

But the success that follows the operation of arteriovenous anastomosis has been attributed to a cause quite distinct from that of the blood going down to the foot through the veins. It has been claimed by some that in the course of doing one of these operations the little nerve fibrils that are to be found in the sheaths of the vessels and in the walls themselves are cut, and that in

this way the relief of pain is obtained, so much so that recently Leriche has called attention to the great relief that has come about merely from stripping the sheaths from the affected vessels. It is still too early to say whether this is so, but his observation at least is interesting and will bear further watching.

In certain cases of threatened gangrene where amputation was not absolutely indicated, or where it seemed wise to procrastinate, I have ligated the femoral vein just below Poupart's ligament and above the entrance into it of the profunda vessels. The reason for this is that with all the channels of inflow to the affected member occluded, what little blood does get down to the foot is drained away too quickly by veins which are not occluded. In other words the patient's veins in these cases act as a suction apparatus, so that even where there is a fair amount of blood getting down to the distal parts of the extremity the tissues are not bathed in the necessary blood and blood juices long enough, because of the fact that the blood is literally sucked away too rapidly. That this is true one can tell by the fact that the venous pressure in these cases is practically *nil*. I have carried out this very mild operation of ligation in a number of instances, and have noted that the veins below, which were previously in a state of collapse, have at once filled out, the whole limb has taken on a bluish-red color, and from the very moment of ligation the temperature of the leg has risen. The venous pressure, too, which formerly had been negative, became positive and remained so. In addition to this, in several instances the pain has been definitely relieved and certain of the sloughing ulcers have taken on a healthy state and have gradually healed. None of my cases, however, have obtained permanent relief from this measure, so that I do not offer it as a cure. Perhaps if it were done in the early stages of the disease certain of the inevitable sequelæ might be avoided and a more lasting benefit might come from it. The procedure therefore is still in the state of trial.

The only operative measure, therefore, that remains is amputation, and in this connection a number of definite points must come in for consideration, far more, I think, than one would ordinarily believe. It is well known that patent's suffering from diabetes do not stand operation of any kind well, so that wherever possible they should not be subjected to such interference. This is especially true of those who have not only sugar in their urine but have acetone and diacetic acid as well. It is at times possible to free the urine of sugar but extremely difficult to get rid of the acetone and diacetic acid, and even when this is possible, general anesthetic and operation is extremely hazardous. In certain cases, though, the condition is such that the extremity must be removed and the patient take his chances. In others,

such as, for example, one that I now have under my care, it is possible to do an amputation by very slow, gradual and painless methods, at least an amputation that involves only about one-half of the foot. The man in question is quite weak, is on a most rigid diet and has acetone and diacetic acid, although he has been under a most rigorous treatment by a competent specialist for many weeks. It might be possible to take this patient's foot off, but the outcome is extremely doubtful, so that I am merely amputating one toe at a time as the gangrenous process permits. He is suffering from a slow, creeping form of gangrene, so that it is possible to remove the dead tissue without pain and therefore without anesthesia of any kind. In this way the patient's general condition is not all influenced. His hospital stay will, of course, be very much longer, but the outcome is far less problematical.[1]

In conditions other than diabetes the problem is not so difficult and depends mostly on the patient's age and general condition. A more pertinent question concerns the point at which amputation should be done. This remains an open one in the minds of most men, but as far as I am concerned my decision is made. In gangrenes consequent upon arteriosclerosis, thromboangiitis obliterans and allied conditions it is my custom to remove the leg just above the knee. I know full well that amputations below the knee are supposed to give better stumps for artificial leg purposes, but it has been my experience that in these conditions of gangrene, amputation performed below the knee only too often has to be followed by a secondary removal because of the fact that the stump does not heal. And this is not hard to understand, because of the fact that in nearly every case of this kind the artery is blocked almost throughout its entire extent, and since the leg is dependent on its collateral circulation for the most part it is only logical that there should be difficulty in healing. Indeed, this difficulty of healing is so great that even when amputation is carried out above the knee it is rare to get healing by anything like first intention, at least rare in my experience. In a certain few instances where the popliteal artery is still competent and pulsating it may be permissible to remove the leg below the knee; but even in these cases it is more than likely that in course of time this popliteal artery will become occluded and trouble will be encountered in the stump later as a consequence.

I have under my care at the present time a man, hardly thirty years of age, who is suffering from Raynaud's disease. He had one of his legs removed below the knee some eight to ten years ago. During all this time he has had to be on his guard con-

[1] Since writing the above a midcalf amputation was successfully accomplished on this patient.

stantly because of the development of little areas of necrosis in the stump. Indeed, it was months before the stump healed in the first place after the original amputation, and it was a year or more before he was ever able to wear a limb. At the present writing he is again in trouble with this stump and the question of higher amputation is under consideration. This man, by the way, came to me some four or five years ago when his right leg got into trouble. At that time his foot was gangrenous and I advised amputation above the knee. He refused absolutely to submit, so I was forced to do the amputation below the knee. The resultant stump never healed and the higher amputation was carried out some six or seven months later. There has been no trouble at all with this stump during all these years.

Within the last few months I have had another case sent me by a well-known surgeon who did his amputation below the knee. The patient was in the hospital seven months, and only then did the stump close by the removal of the projecting ends of both the tibia and the fibula. The resultant stump after this was so sensitive, the skin over it was so tense, and the tissues around the bones so atrophied that the patient never was able to use the artificial limb which he had procured. By appropriate massage, and by the use of the vibrator and constant prodding, I have succeeded in having this man use his artificial limb, but his complaints are continuous, and it is a foregone conclusion that eventually he will have to have another amputation above the knee. Experiences of this sort are not exceptional—they are the rule—so that my own mind is firm that amputation, in practically every case of the gangrenes I have mentioned, should be carried out just above the knee.

In the above pages I have attempted to describe the part played by pain in the various forms of gangrene. Insidious in its onset, extremely difficult to deal with, indescribably excruciating at times, it overshadows practically all other features connected with the disease. So much so that more than one limb that could have been saved has had to be sacrificed because the patient was unable to withstand the ravages of pain that went with his condition. But amputation is merely a conviction of weakness. Far better is it to save and to recreate rather than to destroy. I have pointed out various measures that in my hands have yielded results better than I had any reason to expect. It would be interesting to learn what results the same measures would yield in the hands of others.